EDUCATION MODULE

Title: Finding the Efficiency of a Solar Cell.

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Grade Level: Middle School to High School Science – Introduction to Physical Science/Physics
(Modify the Lesson to your students)

Amount of Time: Approximately 2 days.

National Science Education Standards:
Standard B – Transfer of Energy
Standard E – Understanding about Science and Technology

Overview: Students will need some prior knowledge on the subject of power and energy before starting this lab. An introduction should include a definition of efficiency and some examples for calculating efficiency. The teacher may want to differentiate between power and energy.
Power – Ability to do work in an instant.
Energy – Power over a period of time.

In this lab students will use solar cells to obtain the amount of power (watts) that their solar cell is producing. After collecting individual data, we will use class data to calculate the efficiency of this type of solar cell.

Purpose: The main objectives of this lab are for the students to get a working knowledge of energy and of solar cells. Students will also learn to calculate energy efficiency of solar cell. With the class data, students will use a histogram to answer a question using the scientific method.

Learning Objectives:
After completing this lesson, students will be able to:
- Have a working knowledge of solar energy
- Calculate efficiency of a solar cell
- Use individual data to answer a question
- Use class data to answer a question
- Use a graph/histogram to find an accurate scientific answer
- Conduct an inquiry using the scientific method

Rubric:
Group Work Rubric:

Criteria	Non-proficient	Proficient	Advanced
Teamwork	Did not work well with team	Worked well with team collecting data	Worked well with team and was a team leader
Data Collection	Collected no data	Collected all data	Collected all data and used correct units

Individual Work Rubric:

Criteria	Non-proficient	Proficient	Advanced
Calculations	Did not meet passing requirements	Had most answers correct	All answers correct
Graphs	Graphs incorrect No units Incorrect labels	Most graphs correct Units and labels mostly correct	All graphs correct All labels and units correct
Questions	Answered incorrectly	Answered most questions correctly	Answered all questions correctly

Vocabulary:

- Energy
- Solar energy
- Power
- Photovoltaic Cell
- Efficiency
- Photons
- Renewable energy
- Insolation
- Solar Power
- Solar Cell
- Source of Error
- Electricity

Materials

- Solar Cells (8 or 1 for each student)
- Volt/amp meter (8)
- Outdoor work area
- Sunny day
- Wiring (for 8 cells)
- Ruler (8)
- Calculators (8)

Preparatory Activities and Prerequisite Knowledge

Students should be familiar with the definition of energy, power, the law of conservation of energy, energy transfer, the five forms of energy (nuclear/sun, electromagnetic/electricity, chemical, mechanical and heat) and the scientific method. Student knowledge of potential and kinetic energy will be helpful. The introduction before the lab needs to include how to calculate energy efficiency (discussed later in this paper) with several everyday examples. Discussing energy from sunlight (photons) and solar cells would be helpful.

The following Lab should be copied and given to your students.

LAB: Finding the Energy Efficiency of a Solar Cell

Introduction: In today's Lab, you will find the energy efficiency of a solar cell similar to the solar cells NASA uses on its spacecraft.

Purpose: To see energy use and efficiency in everyday setting.
To gain hands on experience with solar energy.
To use the scientific method to answer a problem.

Hypothesis: Make a hypothesis about the efficiency of your solar cell.
(The energy efficiency of an automobile is about 20%. Keep this in mind when formulating your hypothesis.)

I think the efficiency of my solar cell will be about _____ percent because _____

_____.

Materials:

Solar cell	Wiring
Volt/amp meter	Ruler
or multimeter	Protractor

Procedure:

1. Hook up your solar cell to the volt/amp meter (Class Demonstration)
2. With the entire class outside, every student needs to face their cell in the same direction at 45 degrees. This will ensure each solar cell has the same amount of sunlight energy.
3. Have one person in your Lab group hold the cell at 45 degrees.
   Record the voltage from your voltmeter in the table below.
   Switch the meter to read the amperage ('amps')
   Record the amperage from your voltmeter in the table below.
   Switch the meter back to read voltage
4. Repeat step 3 four more times recording your data in the table each time.
5. Calculate the amount of power in watts produced by your cell for all 5 of your trials.
6. Find the average amount of power produced by your trials.
   (Add the power of all 5 trials together and divide by 5)
7. Record your average power on the board.
8. Measure the height and width of your solar cell in cm and record.
9. Finish the calculations on the table below.
10. Do a Histogram of the class data to find what the class says the correct power is.
11. Answer the questions at the bottom of the lab sheet.
12. Write a conclusion.

Data Table:

	Voltage (V)	**Amperage (A)**	**Power (watts)** Power = V * A
Trail 1			
Trial 2			
Trial 3			
Trial 4			
Trial 5			
Avg. power/trial	Avg. = Add all 5 trials / 5		

Solar Cell Height (cm) _____ cm

Solar Cell Width (cm) _____ cm

Area of Solar Cell (sq. cm) _____ cm^2

Convert cm^2 to m^2 _____ m^2
($1m^2 = 10{,}000\ cm^2$)

Histogram: Teachers note, if you are not familiar with Histograms, use the class average.

Histogram the class data from the board on a piece of graph paper.

According to the class histogram what is the most frequently attained power of the solar cell?

Questions:

A solar cell's power output is rated by the amount of power produced divided by the amount of sunlight that hits the solar cell. The average amount of sunlight (insolation) that hits a 1 meter by 1 meter solar cell is between 800 and 1,000 watts (800-1000Watts/m^2).

$$\text{Solar Efficiency} = \frac{\text{Solar Cell Power Out}}{\text{Sunlight Power In} * \text{Cell Area}} = \frac{\text{Watts}}{800\ \text{Watts} / 1m^2 * \text{Cell Area}\ (m^2)}$$

1. Using the information and equations above, figure out the efficiency of the solar cell from YOUR data. Remember that efficiency is never more than 100%.

2. Now figure out the efficiency of the solar cells from the CLASS data.

3. Are the efficiencies from #1 and #2 the same? If not, why might they be different?

4. What is the weather today?

   How would more sunshine affect the power output of your solar cells?

   How would more clouds affect the power output of your solar cells?

   Would you get more power from your solar cells in the summer or winter? Explain.

5. Name and discuss two sources of error in this experiment. How could they affect the results?

Conclusion:
Write a short paragraph explaining what you did in this Lab. Be sure to relate sunlight to electricity (energy) and also include an evaluation of your hypothesis.

Post Lab:
Give the students the actual efficiency of the cells.
Discuss the class results.
Discuss the future of solar energy and other alternative fuels (economics and energy).

Efficiency Discussion for Educators:
Insolation is the amount of energy in direct and indirect sunlight. A good website for insolation data is www.wattsun.com. The book Solar-Thermal Energy Systems by Howell and Bannerot states 800 watts as a good average amount of insolance. This figure will vary depending on your schools latitude, the amount of cloud cover, pollution, the time of day and the time of year. A good rule of thumb would be 800 watts on a cloudy day, 900 watts on a hazy day and a 1,000 watts on a clear sunny day. These estimations should be fairly accurate between 10 am and 2 pm.

Problem:
Find the efficiency of a solar cell that is 40 cm by 40 cm if it produces 15 watts of power on a cloudy day. Remember to convert the area of the cell from cm^2 to m^2 ($1\ m^2 = 10{,}000 cm^2$).

$40 * 40 = 1600\ cm^2$

$1600\ cm^2$ converts to $0.16 m^2$

$$\text{Solar Cell Efficiency} = \frac{\text{Solar Cell Power Out}}{\text{Sunlight Power In}} = \frac{\text{Watts}}{800\ \text{Watts} / 1m^2 * \text{Area of Cell } (m^2)}$$

$$= \frac{15\ W}{800\ W/m^2 * 0.16\ m^2}$$

$$= .1172$$

$$= 11.7\%$$

Practice Lab:

Data Table:

	Voltage (V)	**Amperage (A)**	**Power (watts)** Power = V * A
Trail 1	4.41	.25	1.1
Trial 2			
Trial 3			
Trial 4			
Trial 5			
Avg. power/trial	Avg. = Add all 5 trials / 5		1.1

Solar Cell Height (cm) _____10_____ cm

Solar Cell Width (cm) _____7_____ cm

Area of Solar Cell (sq. cm) _____70_____ cm^2

Convert cm^2 to m^2
$10{,}000 cm^2 = 1m^2$ _____.0070_____ m^2

Questions:

A Solar cells power output is rated by the amount of power produced divided by the amount of sunlight that hits the solar cell. The average amount of sunlight (insolation) that hits a 1 meter by 1 meter solar cell is considered to be 800 watts (800Whours/m^2).

$$\text{Solar Cell Efficiency} = \frac{\text{Solar Cell Power Out}}{\text{Sunlight Power In}} = \frac{\text{Watts}}{800 \text{ Watts} / 1m^2 * \text{Area of Cell } (m^2)}$$

$$1 \text{ m}^2 = 10{,}000 \text{ cm}^2$$

Using the information and equations above, figure out the efficiency of the solar cell from YOUR data on a sunny day. Remember that efficiency is never more than 100%.

$$\text{Solar Cell Efficiency} = \frac{\text{Solar Cell Power Out}}{\text{Sunlight Power In}} = \frac{\text{Average Watts}}{1000 \text{ Watts}/1m^2 * \text{Area of Cell } (m^2)}$$

$$= \frac{1.1 \text{ watts}}{1000 \text{ watts}/1m^2 * .007 \text{ m}^2}$$

$$= .157$$

$$= 15.7\%$$